The
PSYCHOLOGICAL
RECORD

THE SIGNIFICANCE OF AREA FOR
DIFFERENTIAL SENSITIVITY IN
SOMESTHETIC PRESSURE

A. H. HOLWAY AND W. J. CROZIER

· THE SIGNIFICANCE OF AREA FOR DIFFERENTIAL SENSITIVITY IN SOMESTHETIC PRESSURE*

A. H. HOLWAY and W. J. CROZIER

From the Biological Laboratories, Harvard University, Cambridge, Massachusetts.

Differential sensitivity for somesthetic pressure has been studied (8) to extend the basis for certain general rules now known to apply in the description of visual (7, 10), auditory (15, 16), and kinesthetic (11, 12, 13) data involving the discrimination of intensities (2, 3, 9). With hydrostatic pressure ($= P$) as parameter and area of application (A) as variant, differential sensitivity $1/\Delta P$ was found to be a power function of A over the range tested. Circular surfaces were employed, and $1/\Delta P$ is thus also a power function of the circumference (perimeter) of the applied surface as well as of its area (8). It was therefore sought to determine by additional experiments the respective significance of *area* and of *perimeter*.

Procedure—The region selected for stimulation was located, as in the previous tests, at about one-third of the distance from the elbow to the wrist on the volar aspect of the left forearm. The arm was fitted snugly but comfortably into an especially prepared plaster cast, and was wholly relaxed during stimulation. Hair on the arm was removed by shaving. A method of limits was used (continuous change in the direction of increase).

Three pyrex glass containers (*a*, *b*, and *c*) served as standards for stimulation. Standards *a* and *b* were cylindrical in form and were closed at one end by flat circular bases. The area of the circular base of *a* ($= 12.5$ cm.^{2}) was twice that of *b*. The third container, *c*, was made in the form of two coaxial cylinders united by a flat annular base. This standard was so constructed as to provide a surface of application equal in area to that provided by *b* ($= 6.25$ cm.^{2}); the inner and outer circumferences of its annular surface were equal respectively to the circumferences of *b* and *a*. The area for *c* was thus equal to *b*, and also to the *difference* between the areas for *a* and *b*. The perimeter of the annular surface for *c*, on the other hand, was equal to the *sum* of the circumferences for *a* and *b*. These

relations are illustrated in Fig. 1. The shaded sections show diagram-
matically the shapes and relatively the areas of the three surfaces of
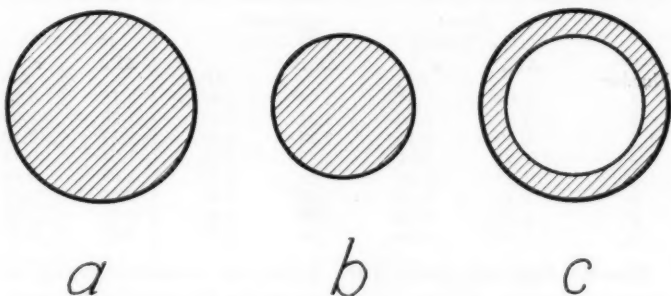application.

$$a \qquad b \qquad c$$

FIGURE 1

Diagrammatic representation of the form, area, and perimeter of the
stimulus-surfaces for containers a, b, and c, respectively.

When loaded, each standard exerted a pressure of 12 gm./cm.²
upon the specified region. A dot of India ink placed on the arm
served to center each surface when applied. To insure against thermal
disturbances, appropriately shaped pieces of thin mat cardboard were
cemented to the bases of the vessels, covering them exactly. During
stimulation the vessels were maintained in a position normal to the
arm surface by means of suitable guides.

Five seconds after the base of a vessel had been carefully placed in
contact with the surface of the arm, the total weight was increased
at the constant rate of 1 gm./sec. by adding water from a calibrated
burette.   (The difference threshold, like the stimulus threshold,
ordinarily varies inversely with the rate of loading (5, 14).   When
the observer had signified that the somesthetic pressure localized in
the forearm had been just noticeably increased in intensity, the experi-
menter recorded the number of grams required to eventuate this
response.   Five measurements were taken with each of the three
cylinders at a single sitting.   The results for eight sittings taken on
two successive days for one observer (A.H.H.) are shown in Table 1.

TABLE I

Results for 8 series of experiments taken at different times with one ob-
server. Each entry is based on 5 measurements. ΔP_m is the average increment
is hydrostatic pressure (g./cm.^{2}) necessary to eventuate a response; $\frac{\sigma}{\Delta P_1}$
is the root-mean-square deviation of the distribution upon which ΔP_m is based.

Series Number	Area a (12.50 cm.^{2})		Area b (6.25 cm.^{2})		Area c (6.25 cm.^{2})	
	ΔP_m	$\frac{\sigma}{\Delta P_1}$	ΔP_m	$\frac{\sigma}{\Delta P_1}$	ΔP_m	$\frac{\sigma}{\Delta P_1}$
1	1.04	0.25	2.04	0.61	2.56	0.53
2	1.47	0.20	3.21	0.65	3.88	1.00
3	0.89	0.16	2.24	0.46	2.33	0.50
4	0.91	0.11	2.27	0.46	1.71	0.44
5	1.25	0.20	3.21	0.79	2.69	0.48
6	0.82	0.25	1.86	0.39	2.06	0.35
7	1.47	0.19	3.15	0.43	2.52	0.57
8	1.35	0.24	2.45	0.31	3.31	0.45

Results—Each ΔP_m entry in the Table is an arithmetic average of
five measurements. Values in the rows are for the designated sittings;
those in the columns are for the areas a, b, and c, respectively. $\frac{\sigma}{\Delta P_1}$
is the root-mean-square deviation of a single observation. The
differences between the ΔP_m values for b and c are not significant.
The values for areas a, however, are in general *less than one-half*
of those for areas b or c. For constant pressure, ΔP_m decreases
with an increase in the area of the applied surface.

Fig. 2 exhibits the result graphically. Curve 1 is based on the
averages given in Table 1; the values in curve 2 are for another
observer. The solid circles in each case are for the circular surfaces
a and b. The open circles are for the annular surface of application,
c. The dashed lines are drawn in accordance with our previous finding
(8) that ΔP_m is a declining power function of A in this range.

Discussion—If one assumes that the number of elements activated
in this experiment is approximately uniformly distributed relative to
the surface of application, the results are consistent with the view that
differential sensitivity increases with an increase in the number of
neural elements available for the discrimination of just noticeable
intensive differences in the affected region during somesthetic
pressure. It is then expected that ΔP_m for b and c should be of the
same order of magnitude and that ΔP_m for a should be least. If, on
the other hand, one were to suppose with Meissner (17), von Frey
(4), von Frey and Kiesow (5), and Hansen (6), that the excitation
proceeded from the *edges* of the stimulating surfaces, then ΔP_m
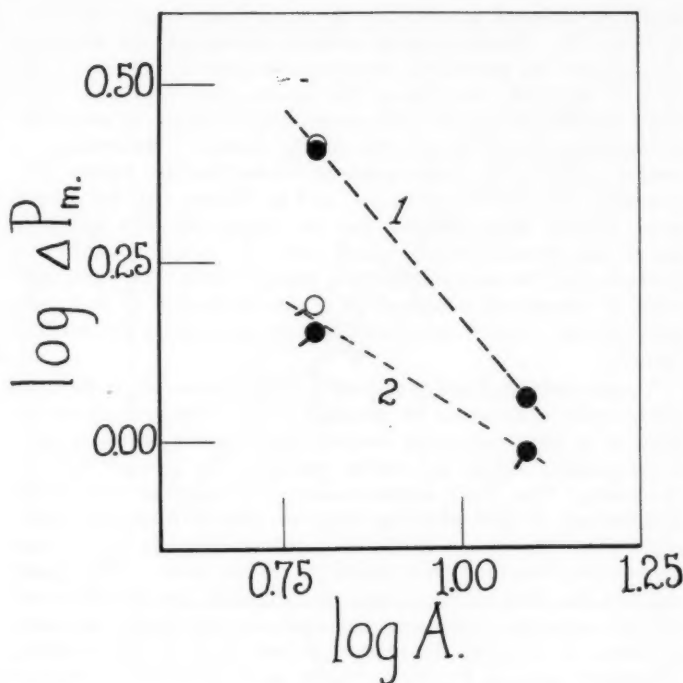should be greatest for b, intermediate for a, and least for c—which is

FIGURE 2

Double-log plot showing ΔP vs A for discs a and b and for annulus c. Function 1 is for A. H. H.; function 2 is for another observer. The solid circles are averages for the circular discs; the open circles, for the annulus. *Area,* and not perimeter, is significant for the determination of ΔP.

certainly contrary to fact. *Mechanical pressure* (gm./cm.²), and not *tension* (gm/cm.), is of critical significance as regards the discrimination of just noticeable intensitive differences for somesthetic pressure.

Although the argument for the use of *tensive* units has not been entirely clear from a physical standpoint, the general idea seems to have been that excitation by pressure is constant when the ratio of exciting force to perimeter of applied area is constant for circular (or approximately circular) surfaces, and that the exciting intensity

should be measured consequently in *tensive* units (= gm./cm.) (*cf.* 4, 5, 6, 17). However, in the present experiment, our observers reported that the somesthetic pressures associated with *b* and *c* were equal in intensity, even though the tension (gm./cm.) of *c* were much less than that of *b*. This observation, of course, is essentially non-quantitative and is therefore hardly decisive. Nevertheless, a careful scrutiny of the results presented by von Frey and Kiesow (5), principally for microscopic stimuli, and by Hansen (6), for macroscopic stimuli, show definitely that for strong and even for weak stimuli the exerted tension varies with A (= kp^2) though less markedly than the exerted hydrostatic pressure varies for a "constant" value of somesthetic intensity. It is thus misleading to deal only with gm./cm., even if one favors tension (stretch) as the exciting agency.

It seems probable that this misleading notion derives originally from introspective observations by Meissner (17). Meissner placed his finger in a vessel containing mercury, and reported that he experienced pressure only at the surface separating the mercury and the atmosphere. Von Frey's reports concerning a repetition and various modifications of this procedure tend to support Meissner's statements (5). The present writers have also attempted to repeat these observations, but have been unable to confirm them. (The point involved here does not hinge upon the distinction between cutaneous and sub-cutaneous impressions, but upon the appearance and locus of either, *i. e.*, upon the occurrence and locus of the resulting somesthetic pressure (4, 6).) Under such conditions a compact pressure, which terminates fairly abruptly at the proximal surface of the mercury, is felt throughout most of the immersed portion of the finger. When the finger was immersed and maintained in a horizontal position, the intensity of the pressure on the *lower* side of the finger (or hand) was always noticeably greater than that on the upper side of the finger. This result is clearly detectable when the mercury is "thermally indifferent."

Variability—It has been emphasized that for the marginal discrimination of intensities a direct proportionality obtains between ΔI_m and $\sigma_{\Delta i}$ and that ΔI_m may be determined by $\sigma_{\Delta I_1}$ rather than the reverse (3). For a particular department of sense, the relationship is unaffected by area, for example, and by certain other variables (2, 3, 7, 12, 13). In terms of ΔP and $\sigma_{\Delta P}$ the data of the present experiments are in precise agreement with this rule. Fig. 3 shows that ΔP_m
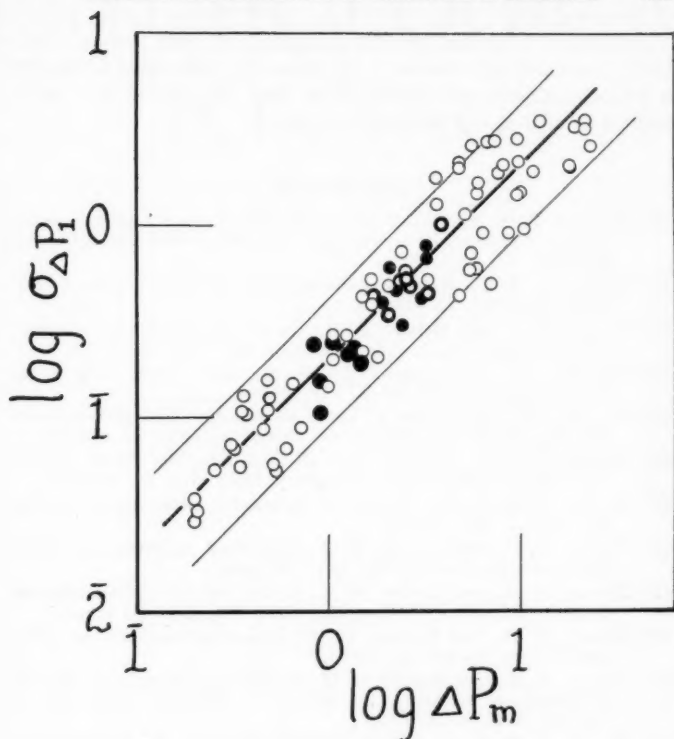
FIGURE 3

The direct proportionality of ΔP_m to $\sigma_{\Delta P}$ is the same for different levels of P_1 and for different areas (Observer No. 1). See text. Open circles, data from (1), including additional experiments; solid circles, data in Table I, for small and large areas; rings, data in Table I, for annulus. The slope = 1. On a log-log grid the proportionality of σ_{σ_1} to σ_1 causes the points to form a ribbon of statistically constant breadth if the data are homogeneous.

is the same function of $\sigma_{\Delta P}$ when the level of P_1 is altered, when A is altered, and when the form and perimeter of the applied area are changed. Differential sensitivity is directly proportional to discriminatory precision. In these respects also, then, P and ΔP correspond to I and ΔI for visual, auditory, and kinesthetic excitation.

Conclusion—One conclusion is demanded for these results. Me-chanical pressure, not tension, is significant for differential sensitivity in somesthetic pressure. Excitation in these experiments is a direct function of *area* and of *mechanical pressure*.

BIBLIOGRAPHY

(1) Churcher, B. G., King, A. J., and Davies, H., The minimum perceptible change of intensity of a pure tone, *Phil. Mag.*, 1934, *18*, 7th series, 927-939.

(2) Crozier, W. J., On the sensory discrimination of intensities, *Proc. Nat. Acad. Sci.*, 1936, 22, 412-416.

(3) Crozier, W. J., and Holway, A. H., On the law for minimal discrimi-nation of intensities, I, *Proc. Nat. Acad. Sci.*, 1937, 23, 23-28.

(4) Von Frey, M., Die Tangoreception des Menschen, *Hdbk. d. Norm. u. Pathol. Physiol.*, 1926, Bd. XI (I), 94-100.

(5) Von Frey, M., and Kiesow, F., Ueber die Function der Tastkörperchen, *Ztschr. f. Psychol. u. Physiol. der Sinnesorg.*, 1899, 20, 126-163.

(6) Hausen, K., Neue Versuche ueber die Bedeutung der Fläche für die Wirkung von Druckreizen, *Zeitschr. f. Biol.*, 1913, 62, 536-550.

(7) Holway, A H., On the precision of photometric measurements, *J. Opt. Soc. Amer.*, 1937, 27, 3.

(8) Holway, A. H., and Crozier, W. J., Differential sensitivity for somes-thetic pressure, *Psychol. Rec.*, 1937 (in press).

(9) Holway, A. H., and Crozier, W. J., on the law for minimal discrimi-nation of intensities, II, *Proc. Nat. Acad. Sci.*, 1937 (in press).

(10) Holway, A. H., and Hurvich, L. M., Differential sensitivity to white light, *J. Gen. Psychol.* (in press).

(11) Holway, A. H., and Hurvich, L. M., On the discrimination of minimal differences in weight: I. A theory of differential sensitivity, *J. Psychol.*, 1937, *4*, 309-332.

(12) Holway, A. H., Smith, J. E., and Zigler, M. J., On the discrimination of minimal differences in weight: II. Number of available elements as variant, *J. Exper. Psychol.*, 1937, 20, 371-380.

(13) Holway, A. H., Smith, J. E., and Zigler, M. J., On the discrimination of minimal differences in weight: III. The role of frequency, *J. Exper. Psychol.*, 1937 (in press).

(14) Stratton, G. M., Ueber die Wahrnehmung von Druckveränderungen bei verschiedenen Geschwindigkeiten, *Philos. Stud.*, 1896, *12*, 525-586.

(15) Upton, M., and Holway, A. H., On the psychophysics of hearing: I. Monaural differential sensitivity and exposure-time, *Proc. Nat. Acad. Sci.*, 1937, 23, 29-32.

(16) Upton, M., and Holway, A. H., On the psychophysics of hearing: II. Binaural differential sensitivity and exposure-time, *Proc. Nat. Acad. Sci.*, 1937, *23*, 32-34.

(17) Wagner, R., and Meissner, G., Ueber das Vorhandensein bisher unbe-kannter eigenthumlicher Tastkörperchen in den Gefühlswarzchen der Menschlichen Haut und über die Endausbreitung sensibler Nerven, *Göttingen Nachrichten*, 1852, 17-32; cf., also, Meissner, G., *Ztschr. f. rat. Med.*, 1853, 7, 3rd series, esp. p. 99 ff.